WELCOME

Understanding and Using Geometry, Projections, and Spatial Reference Systems in ArcGIS

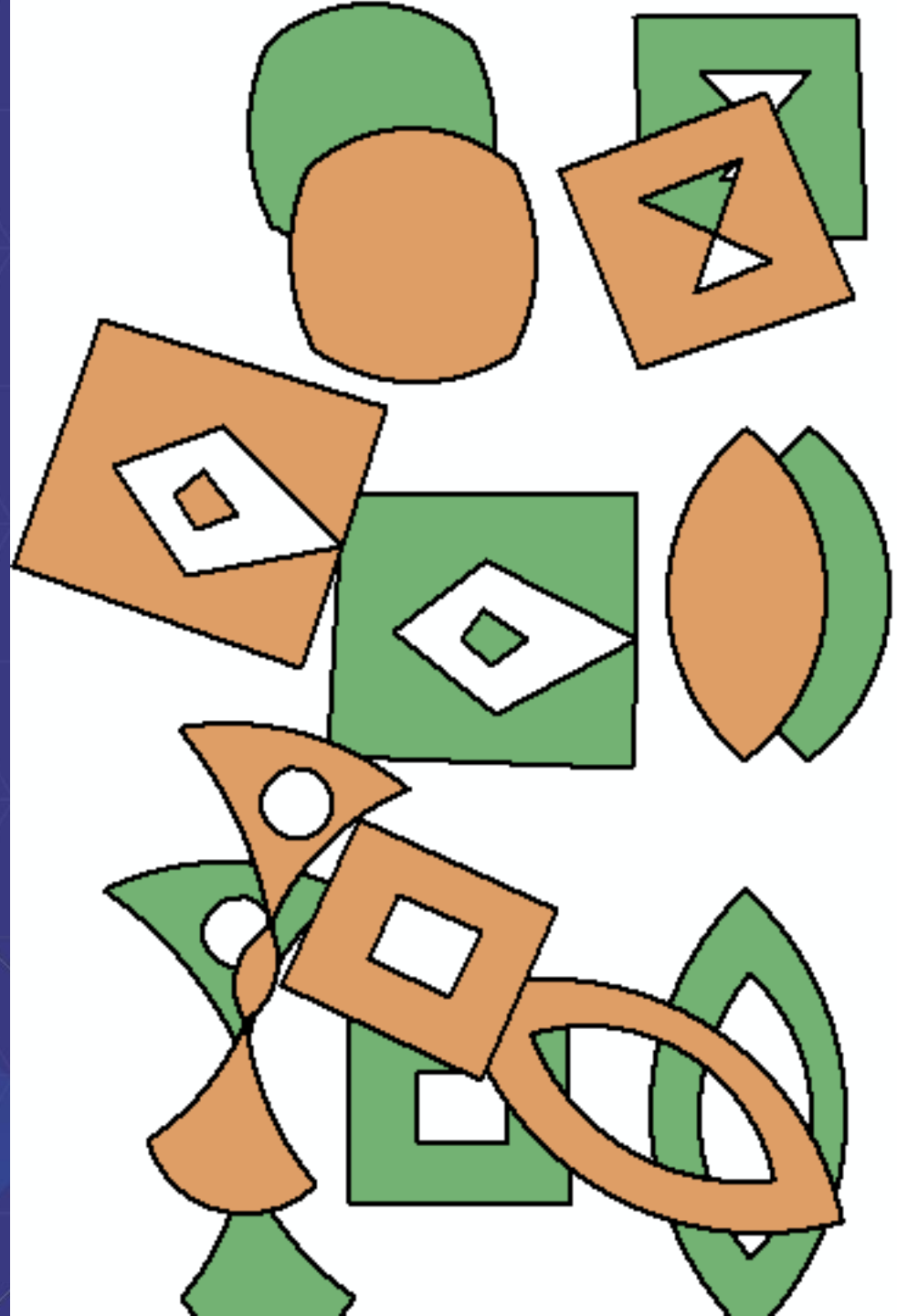
Rob Juergens, Melita Kennedy, Annette Locke

Introduction

We want to give you a basic understanding of geometry and spatial references

- We won’t show you code
  - Our libraries are low level
  - Many APIs built on top
- We will talk about
  - Geometry types
  - Spatial references and their properties
  - How geometries and spatial references interact

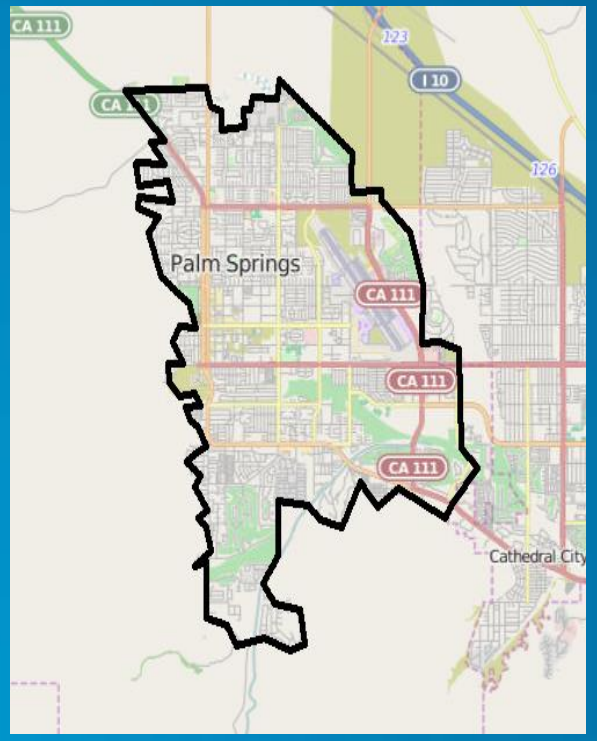
Geometry

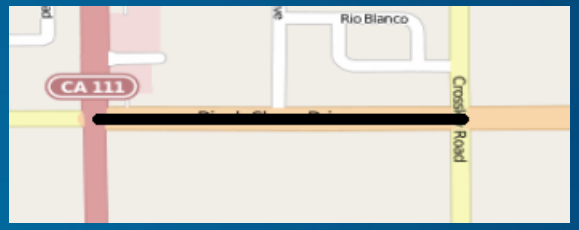


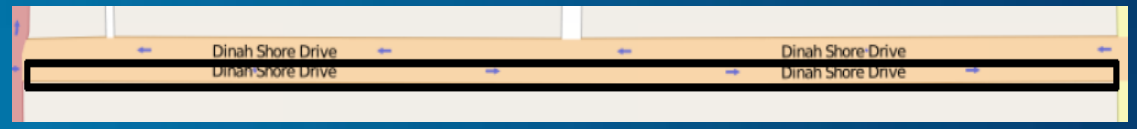
What is a geometry?

- Defines the shape of a feature

- Points, lines, and polygons represent real-world objects

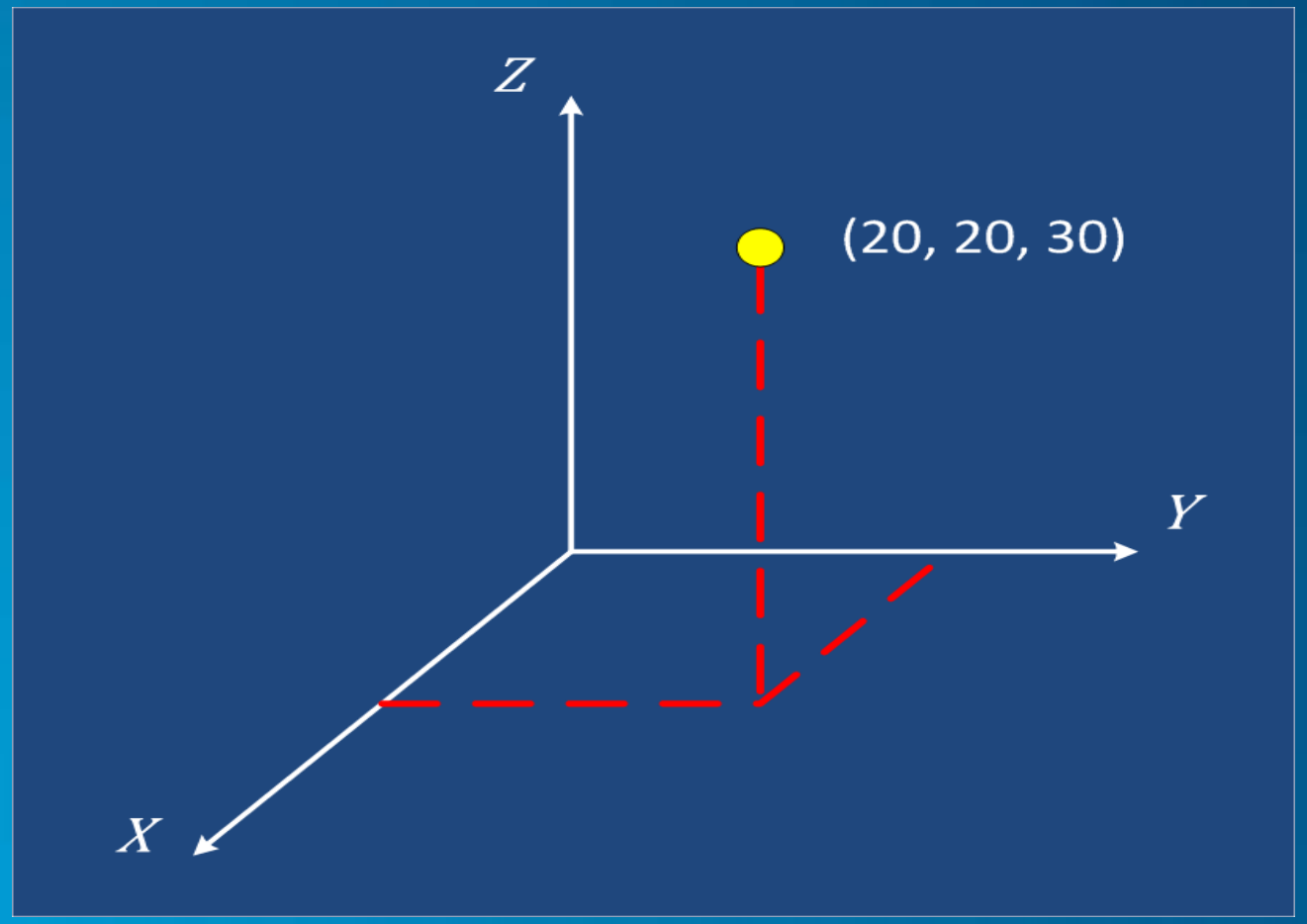






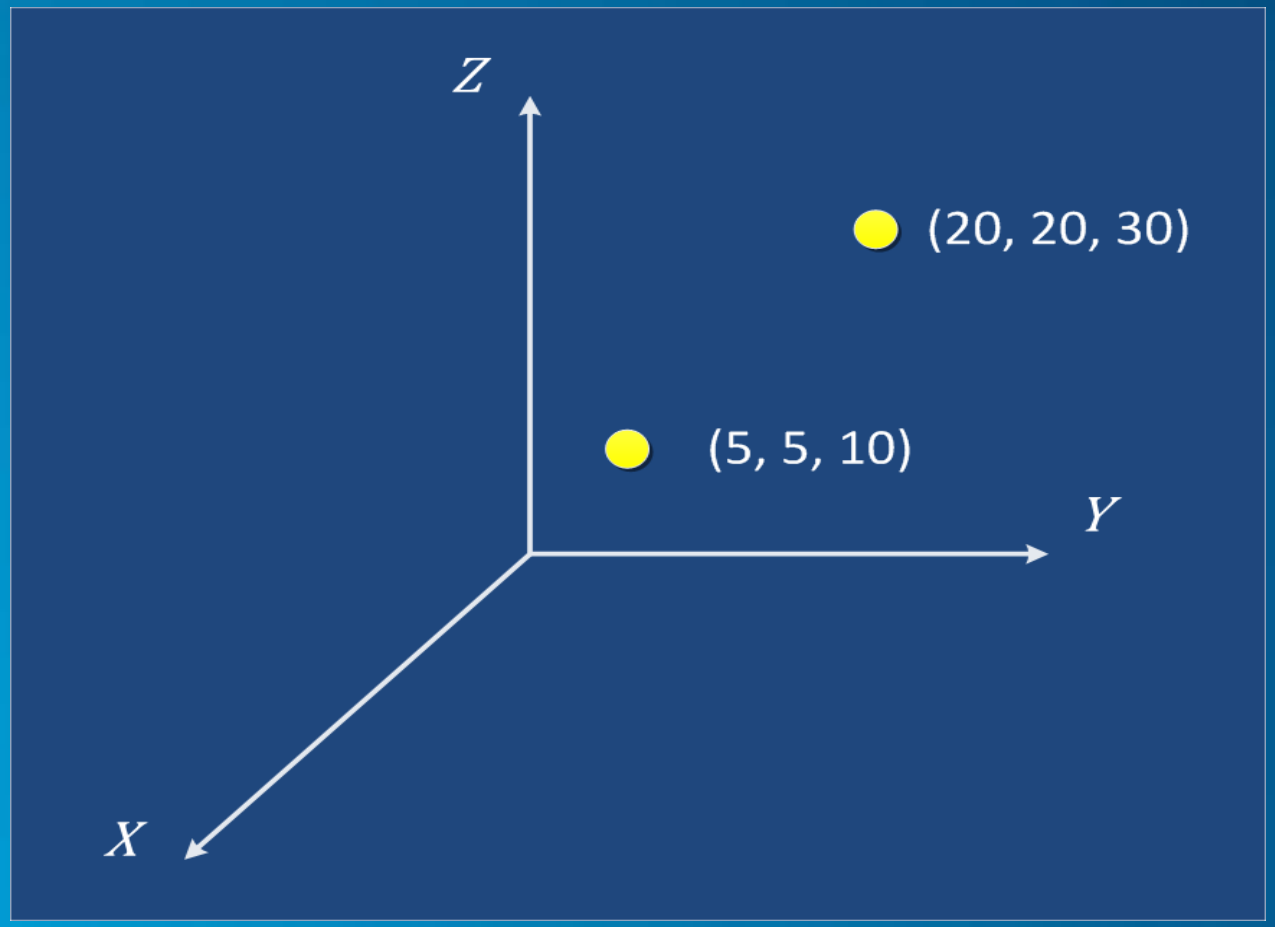
Points

Building blocks for all geometries



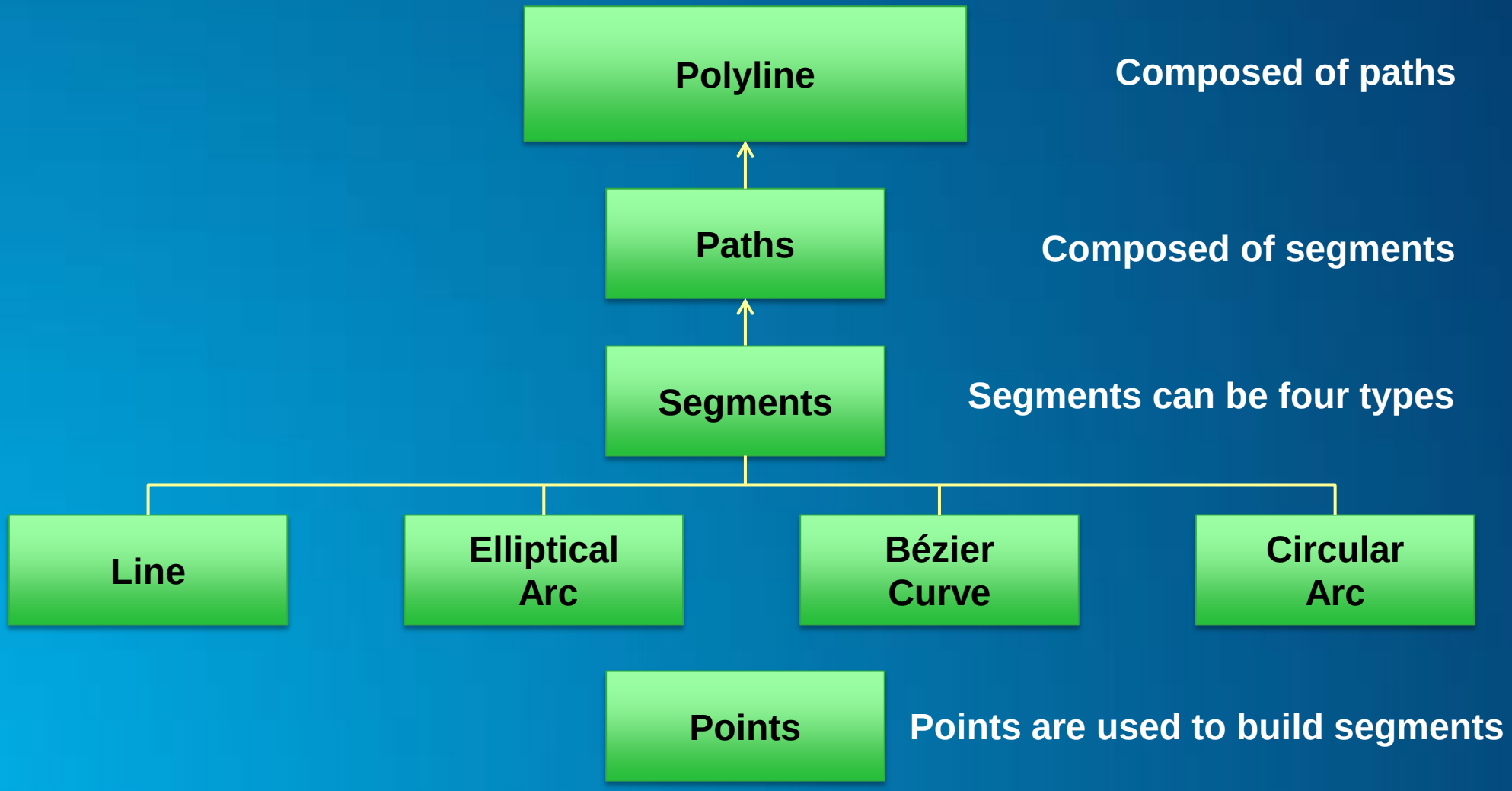
Multipoints

Each multipoint feature is a collection of points

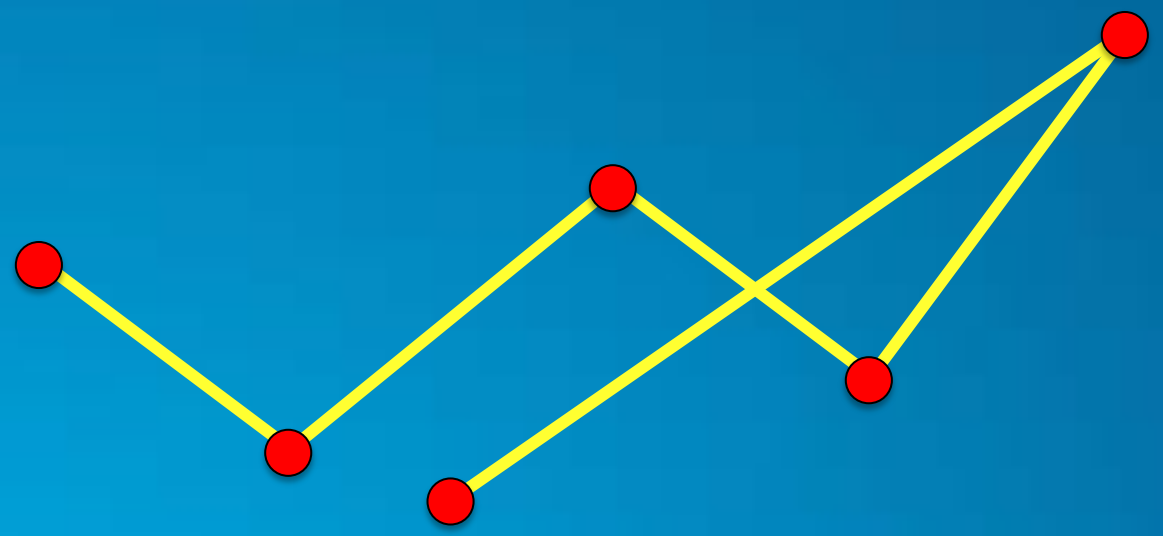


Polylines

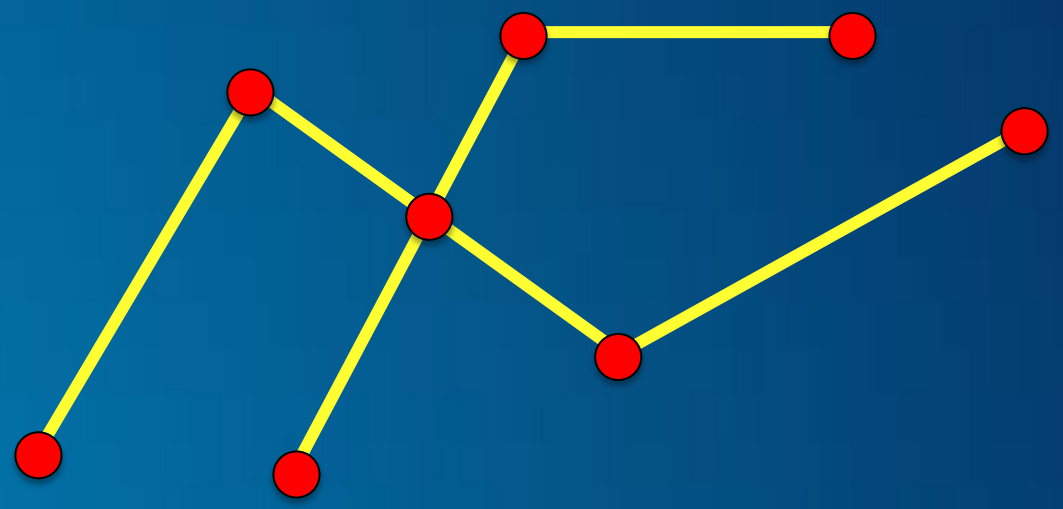
A collection of paths



Polylines



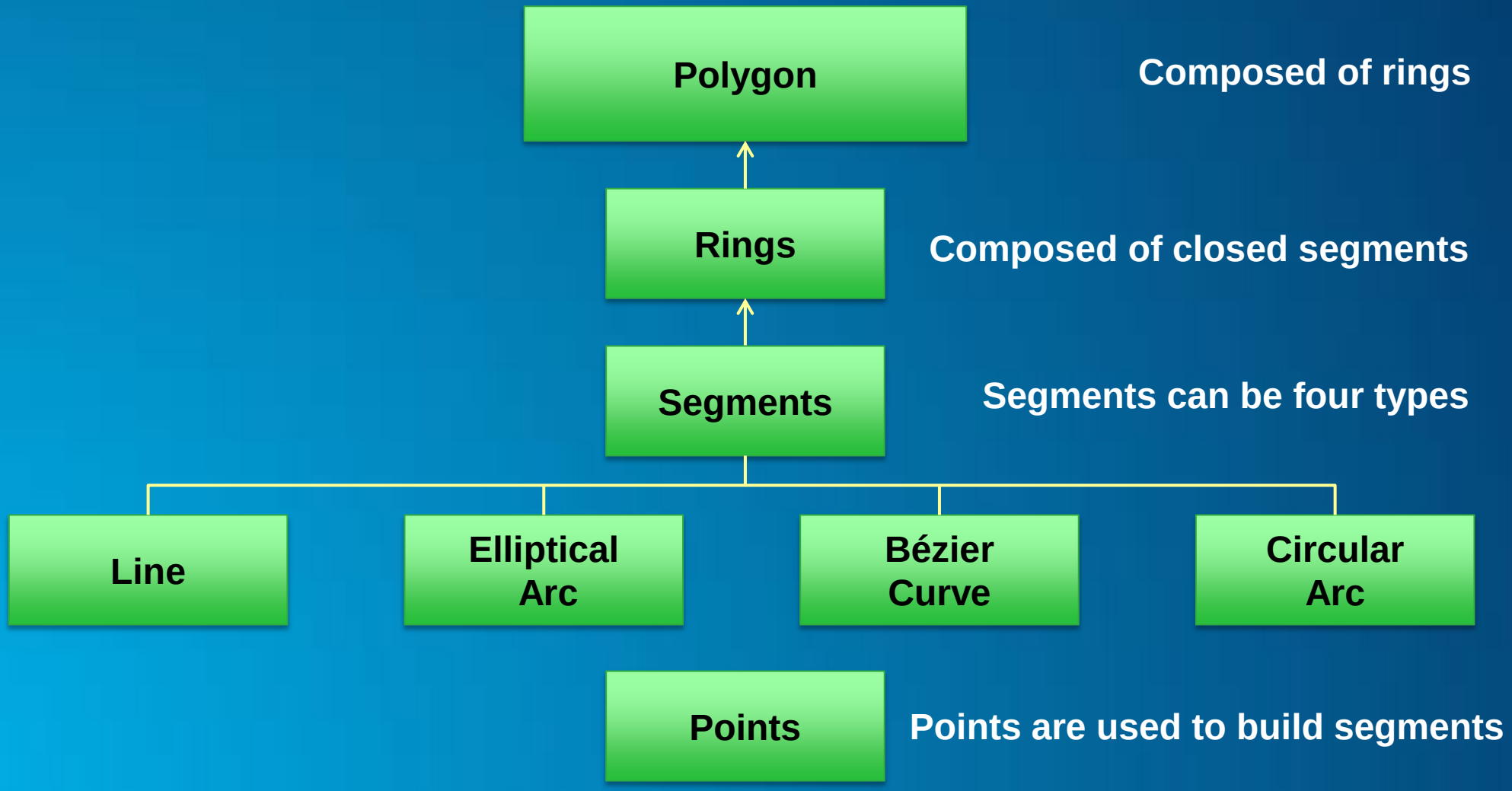
Single part



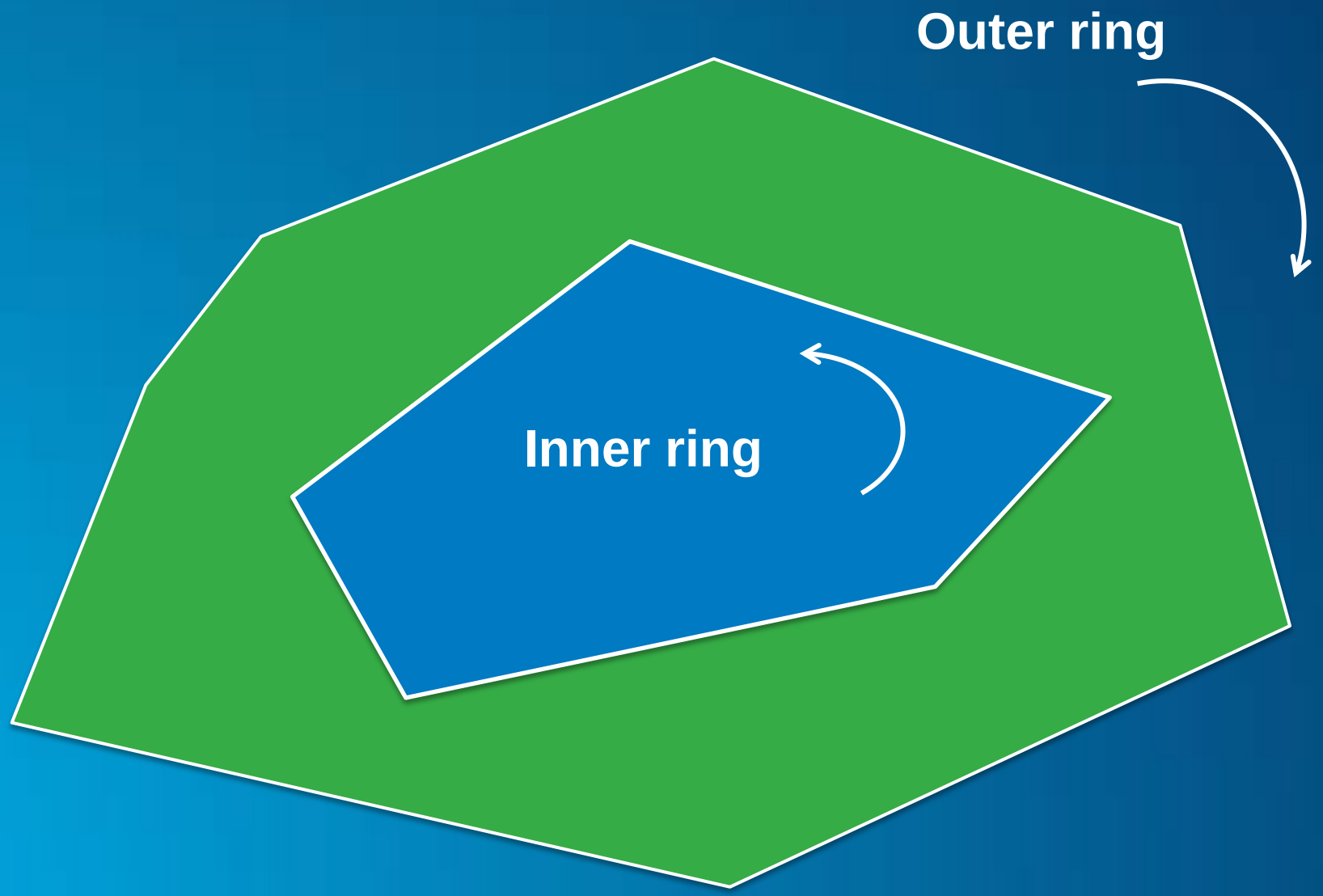
Multipart

Polygons

A collection of rings



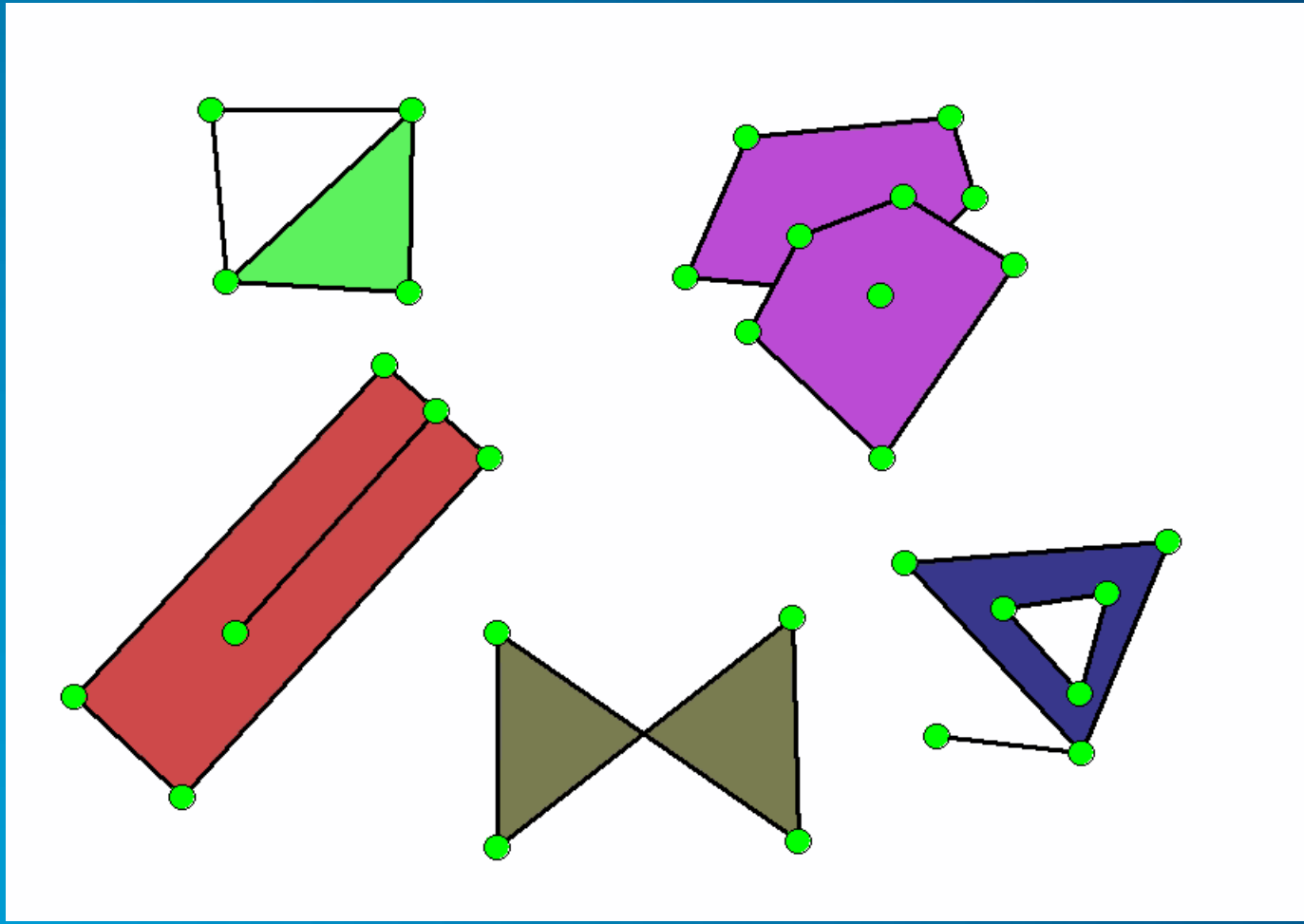
Polygons



We want “valid” geometries

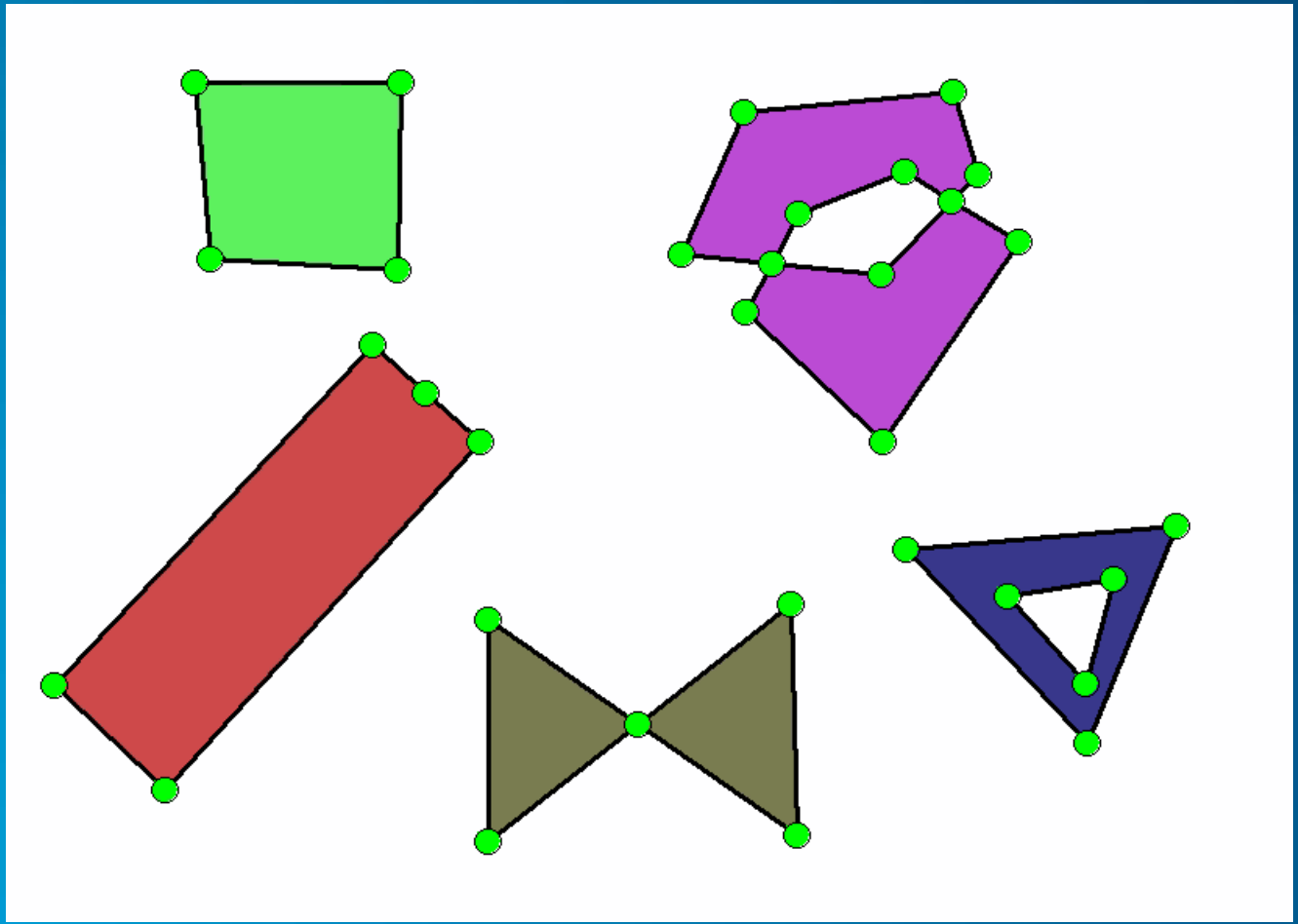
- What?
  - Adhere to a specified set of topological rules
  - Known as “simple”
- Why?
  - Storage in a database
  - Cannot rely on results from operations using non-simple geometries
    - Get an error
    - Get incorrect results
- How?
  - ArcGIS Pro and ArcMap
    - Check Geometry and Repair Geometry GeoProcessing tools
  - ArcGIS Server
    - IsSimple and Simplify operations
  - All Esri APIs have similar functionality

Non-simple Polygons



Simple Polygons

Simplifying may add or remove vertices



Why do we care if geometries are simple?

Demo

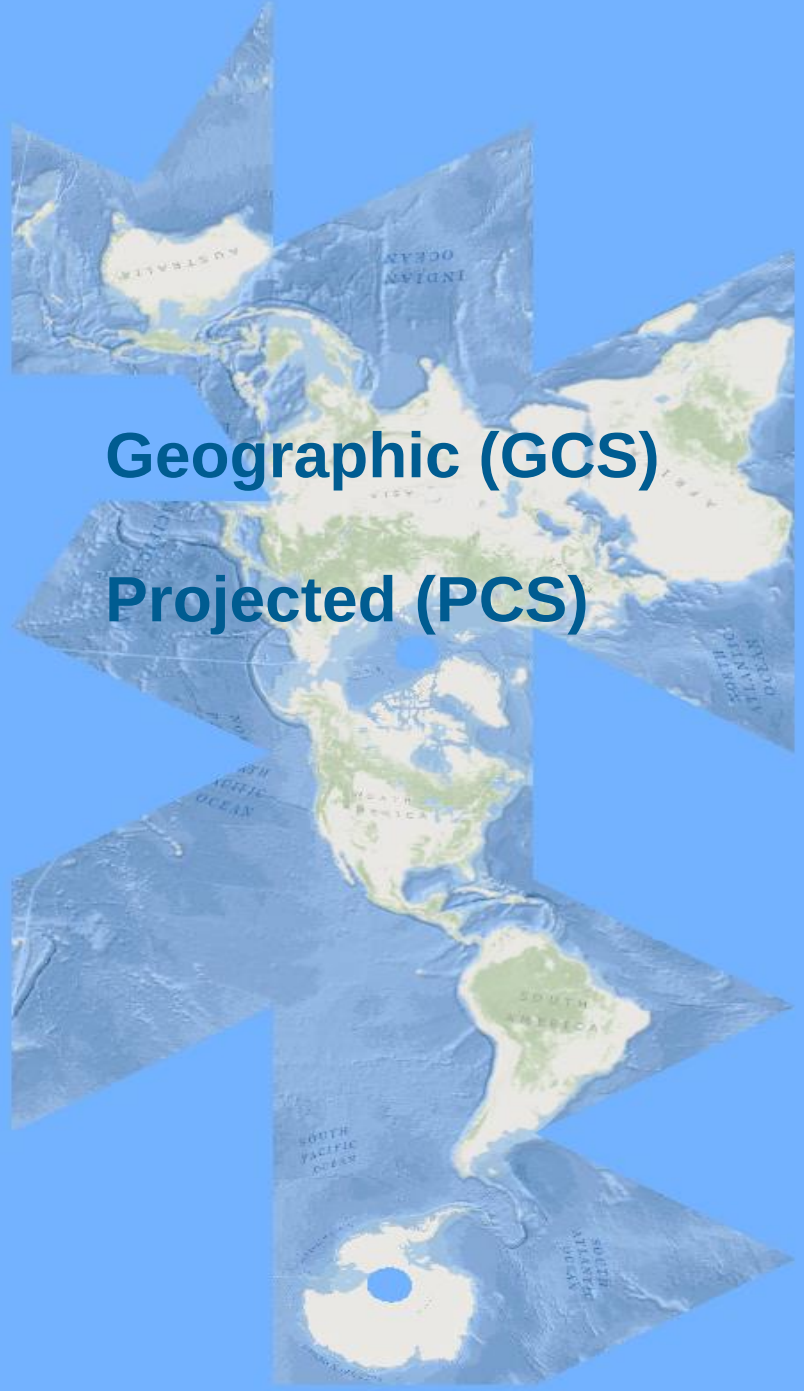
Spatial References

```
ld_Mercator",
CS_WGS_1984",
_WGS_1984",
[ "WGS_1984", 6378137.0, 29
Greenwich", 0.0],
ree", 0.0174532925199433] ],
[ "Mercator " ],
[ "Central_Meridian", 0.0],
[ "Standard_Parallel_1", 0.0],
[ "False_Easting", 0.0],
[ "False_Northing", 0.0],
, 1.0] ]
```

Key properties of spatial references

- Coordinate system
  - Geographic
  - Projected
- XY Resolution
- XY Tolerance

Coordinate Systems



Geographic (GCS)

Projected (PCS)

What is a coordinate system?

- An agreed upon way to describe locations

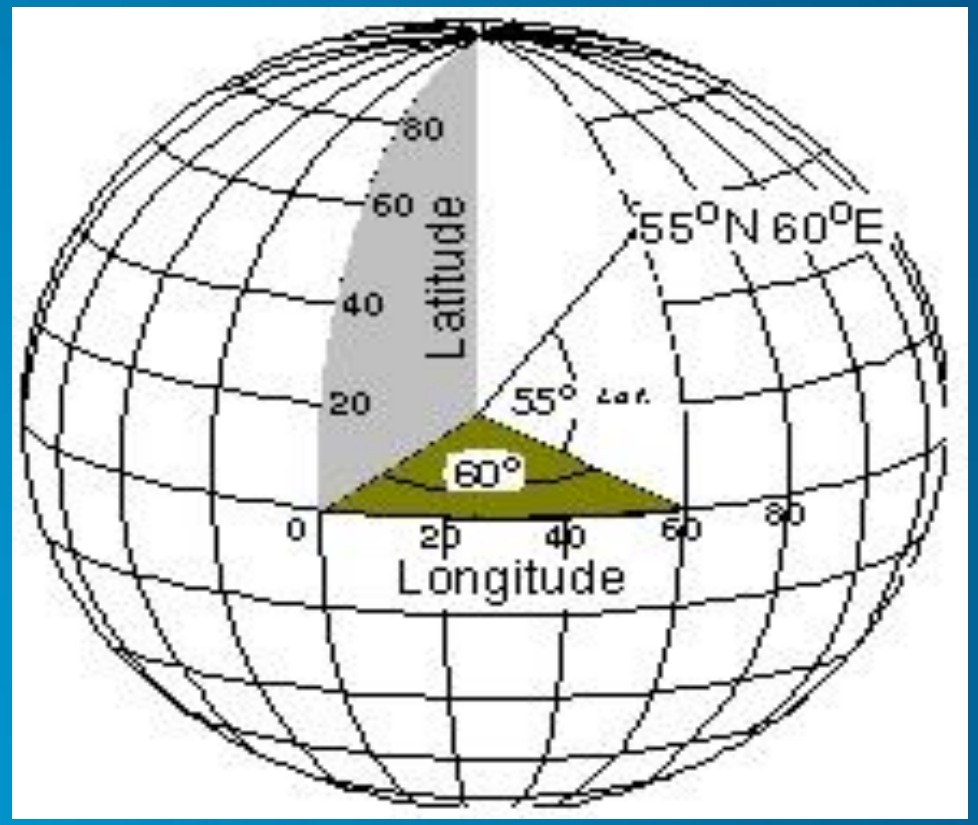
- Represents locations
  - Geographic features
  - Imagery
  - Observations such as GPS locations

- Common geographic framework

  Used to integrate geographic locations from different datasets

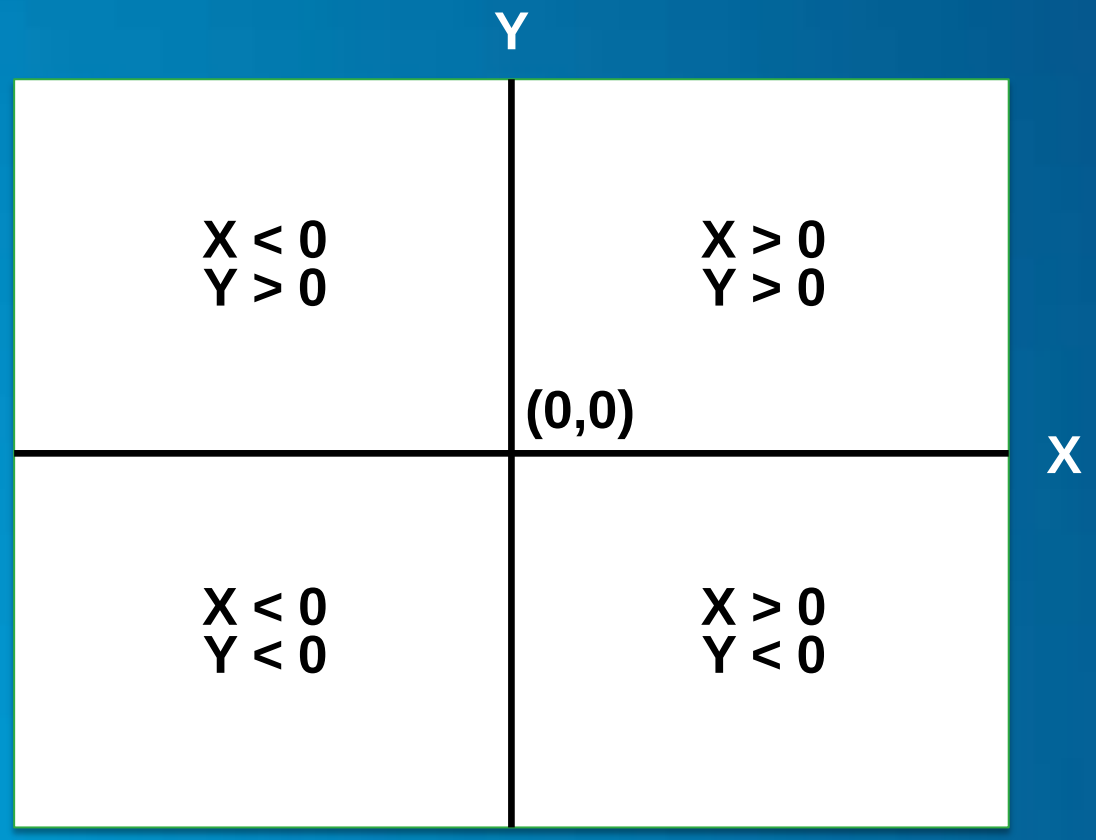
Geographic Coordinate System (GCS)

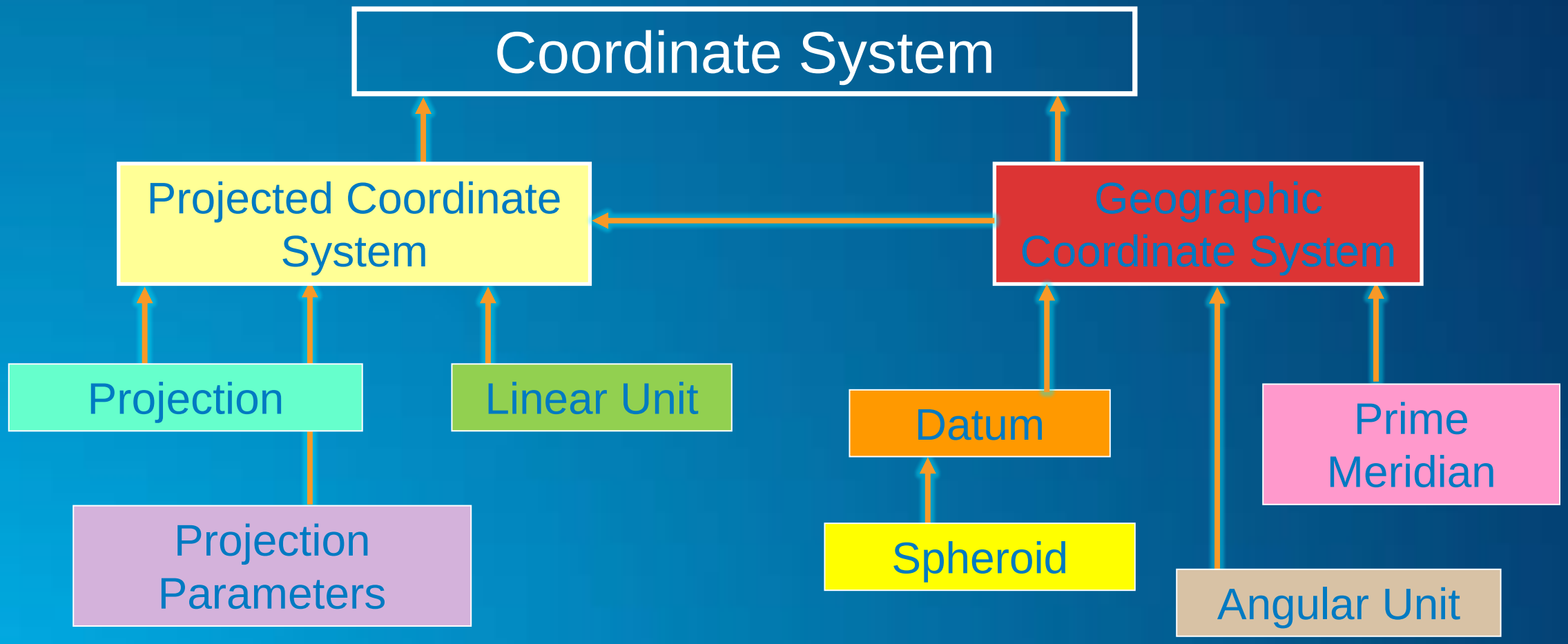
- Global – 3D spherical surface
- Point referenced by longitude and latitude values



Projected Coordinate System (PCS)

- Flat – 2D surface based on a GCS
- Point referenced by x, y coordinates on a grid

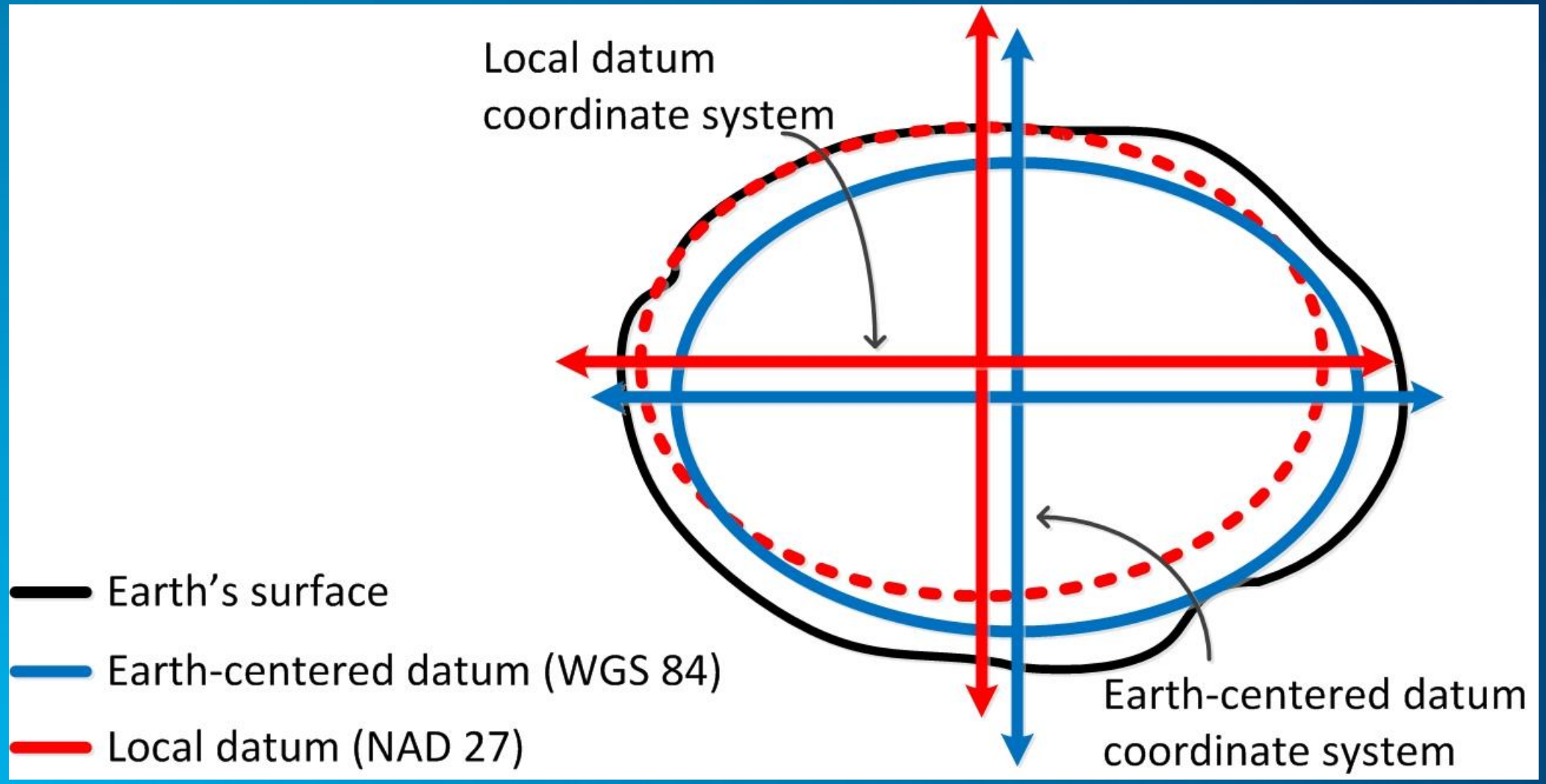



Coordinate System
Projected Coordinate System
Geographic Coordinate System
Projection
Linear Unit
Datum
Prime Meridian
Projection Parameters
Spheroid
Angular Unit

Geographic Coordinate System Well-Known Text (WKT)

```
GEOGCS[ "GCS_WGS_1984",
    DATUM[ "D_WGS_1984",
        SPHEROID[ "WGS_1984", 6378137.0, 298.257223563] ],
    PRIMEM[ "Greenwich", 0.0],
    UNIT[ "Degree", 0.0174532925199433] ]
```

What is a datum?



Projected Coordinate System
Well-Known Text (WKT)

```
PROJCS[ “World_Mercator",
  GEOGCS[ "GCS_WGS_1984",
    DATUM[ "D_WGS_1984",
        SPHEROID[ "WGS_1984", 6378137.0, 298.257223563] ],
    PRIMEM[ "Greenwich", 0.0],
    UNIT[ "Degree", 0.0174532925199433] ],
  PROJECTION[ "Mercator " ],
  PARAMETER[ "Central_Meridian", 0.0],
  PARAMETER[ "Standard_Parallel_1", 0.0],
  PARAMETER[ "False_Easting", 0.0],
  PARAMETER[ "False_Northing", 0.0],
  UNIT[ “Meter", 1.0] ]
```

Well-Known ID (WKID)

- Every predefined coordinate system has a WKID
  - For example, GCS_WGS_1984, WKID = 4326

- WKID < 32767 is EPSG assigned
  - EPSG Geodetic Parameter Dataset, http://www.epsg-registry.org/

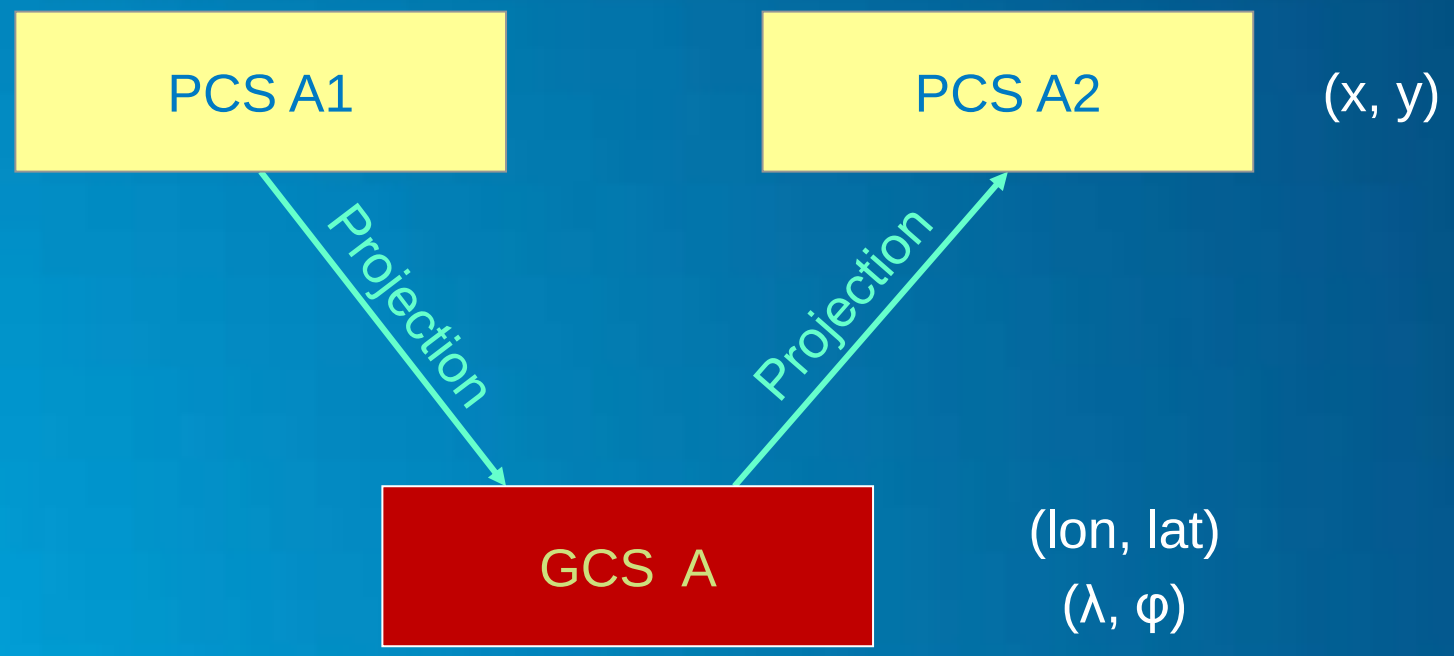
- WKID > 32767 is Esri assigned
  - Esri WKID may change
  - Esri → EPSG
  - Old WKID will still work
  - Example, Web Mercator 102100 → 3857

All projections have some distortion

Web Mercator Projection

What is happening when we project data?

Case 1: Both PCSs contain the same GCS



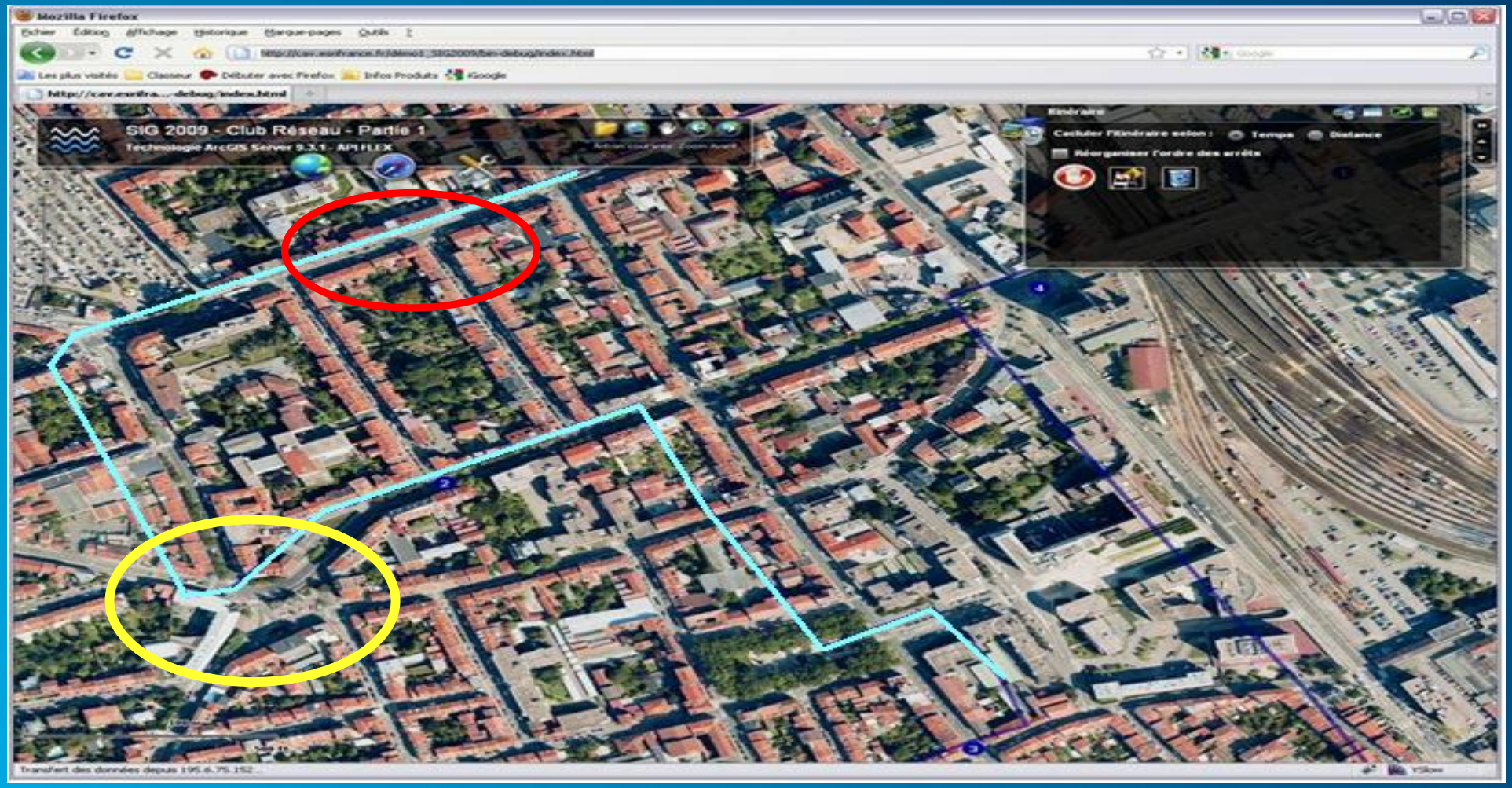
What is happening when we project data?

Case 2: Each PCS contains a different GCS

Geographic Transformations (GT)

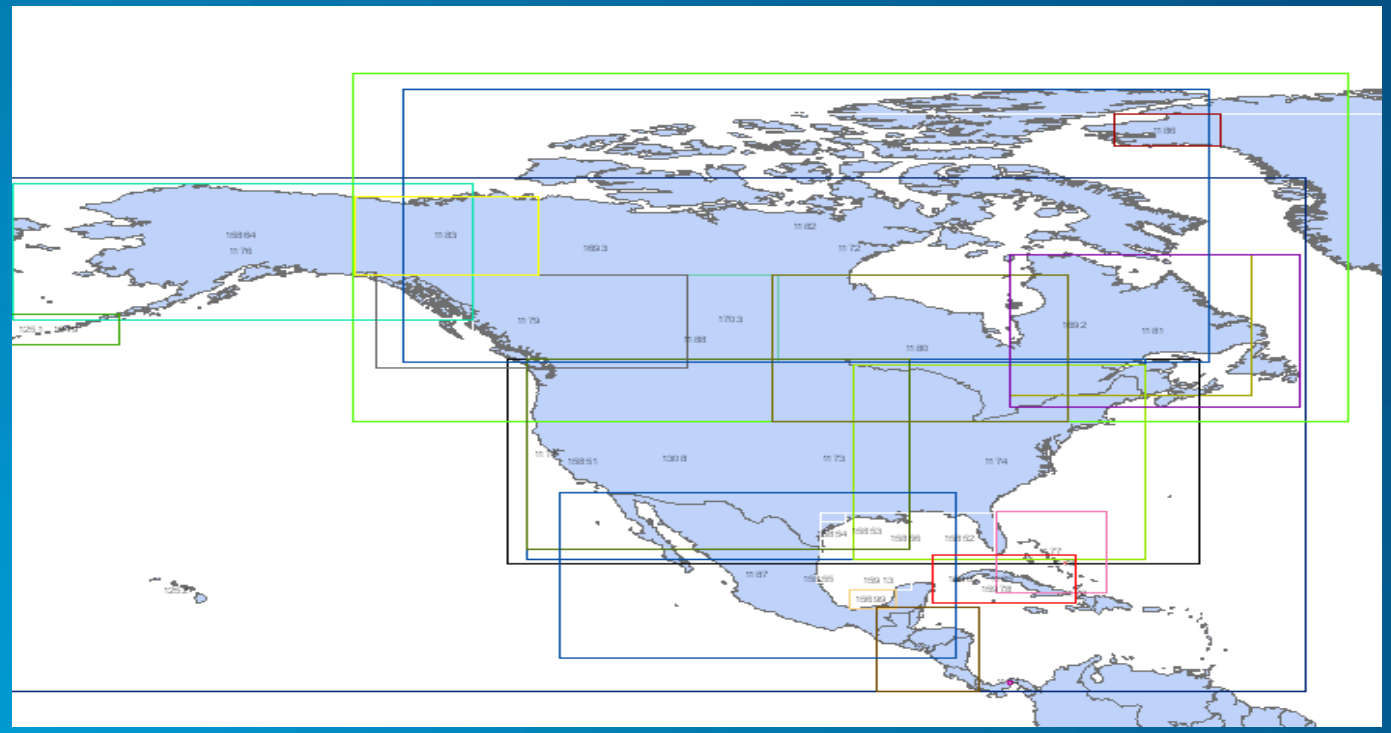
- Convert from one GCS to another GCS
- Suitable for a particular area
- Defined in a particular direction
  - For example, NAD27 to WGS84
  - All are reversible
- May be more than one applicable GT

Why do we need to transform our data?



European Datum 1950 vs. World Geodetic System 1984

There are 38 transformations between GCS_North_American_1927 and GCS_WGS_1984



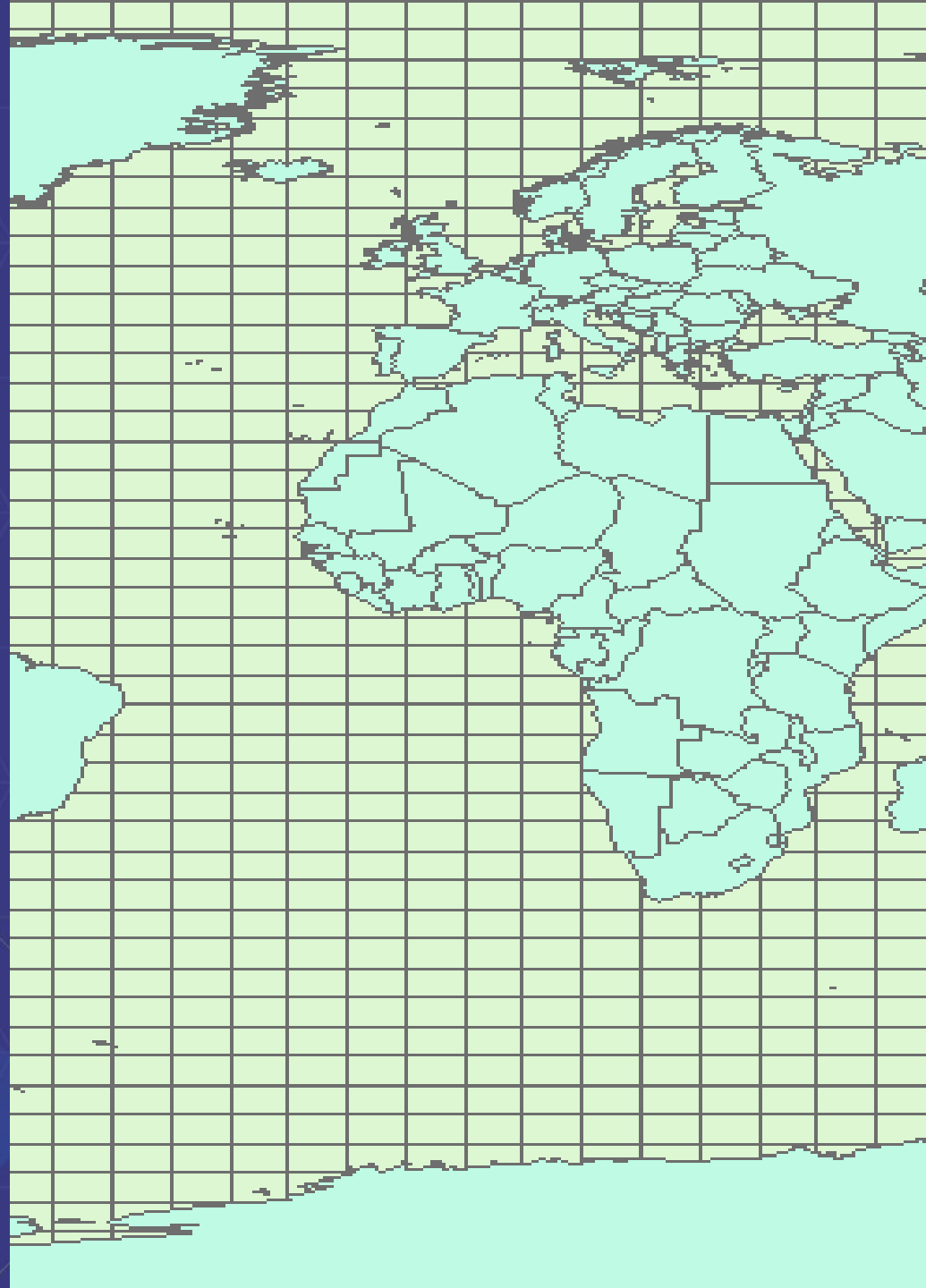
Which is best?

Depends on the region covered by your data

How do I find transformations?

Demo

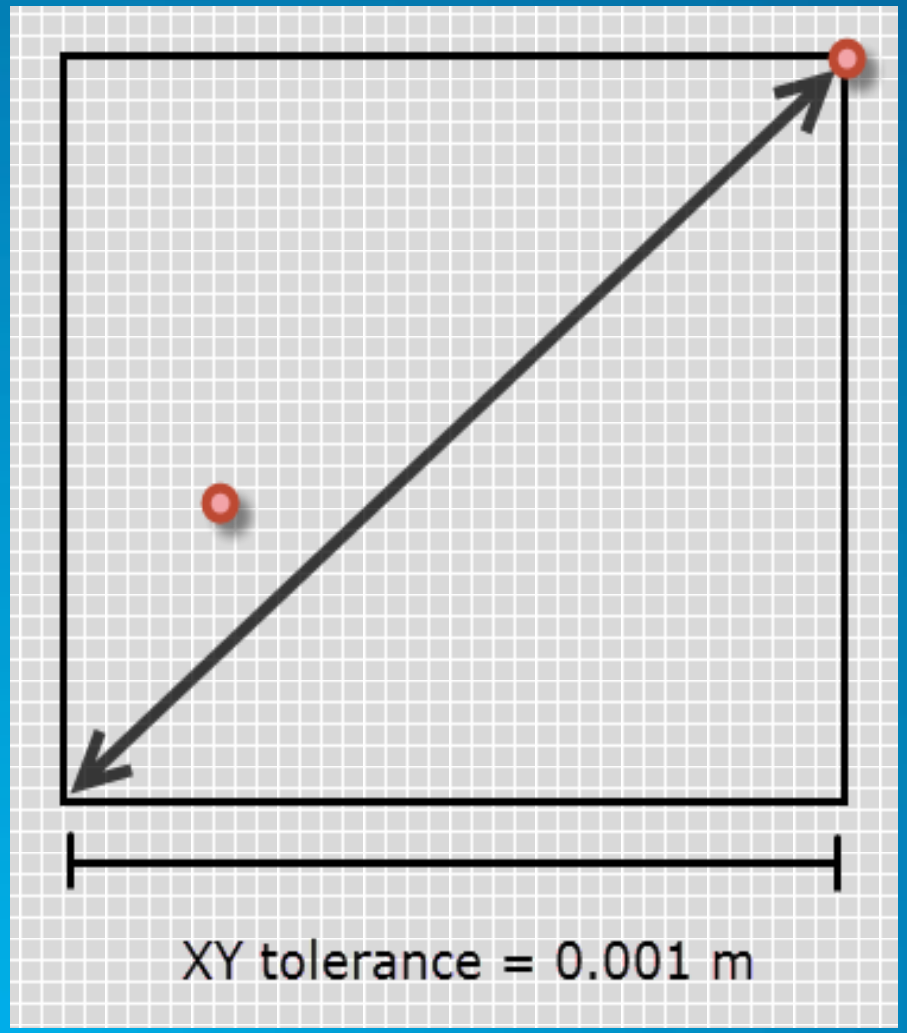
Tolerance and Resolution



XY Tolerance

- Minimum distance between coordinates
- Comes into play when we are working with geometries
  - Make sure our geometries are simple
  - Topological operations
    - For example, Buffer, Symmetric Difference, Union, Intersection
  - Relational operations
    - For example, Disjoint, Touches, Overlaps, Crosses, Within
  - Editing operations

XY Tolerance



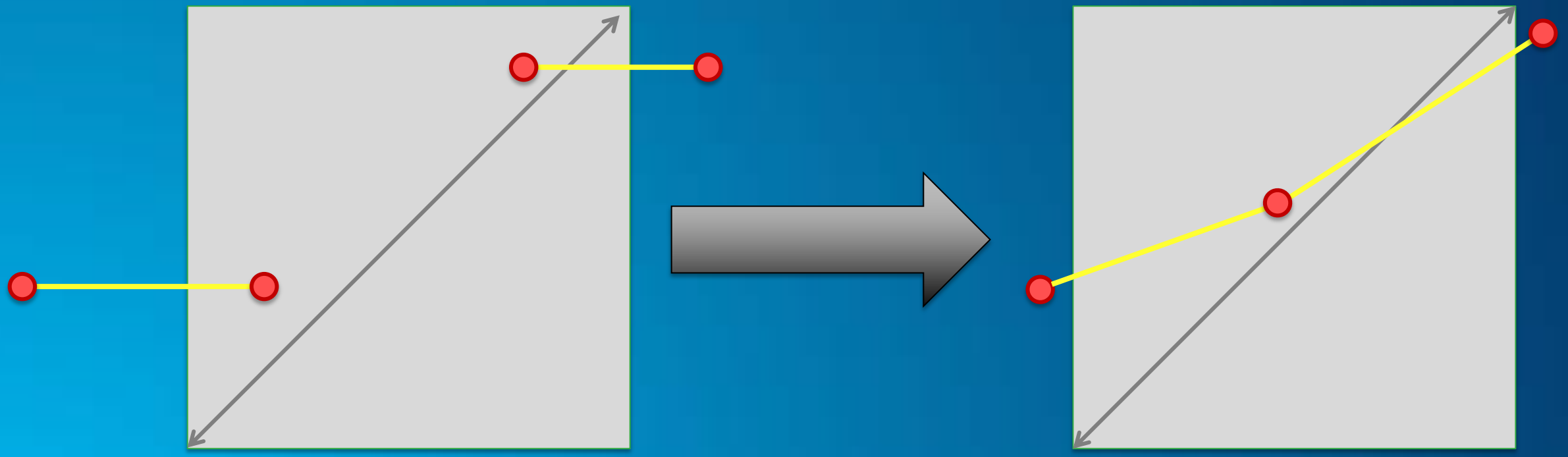
Default value = 0.001 meters or equivalent

Do these two points intersect?

Yes, since the distance between them is less than the tolerance.

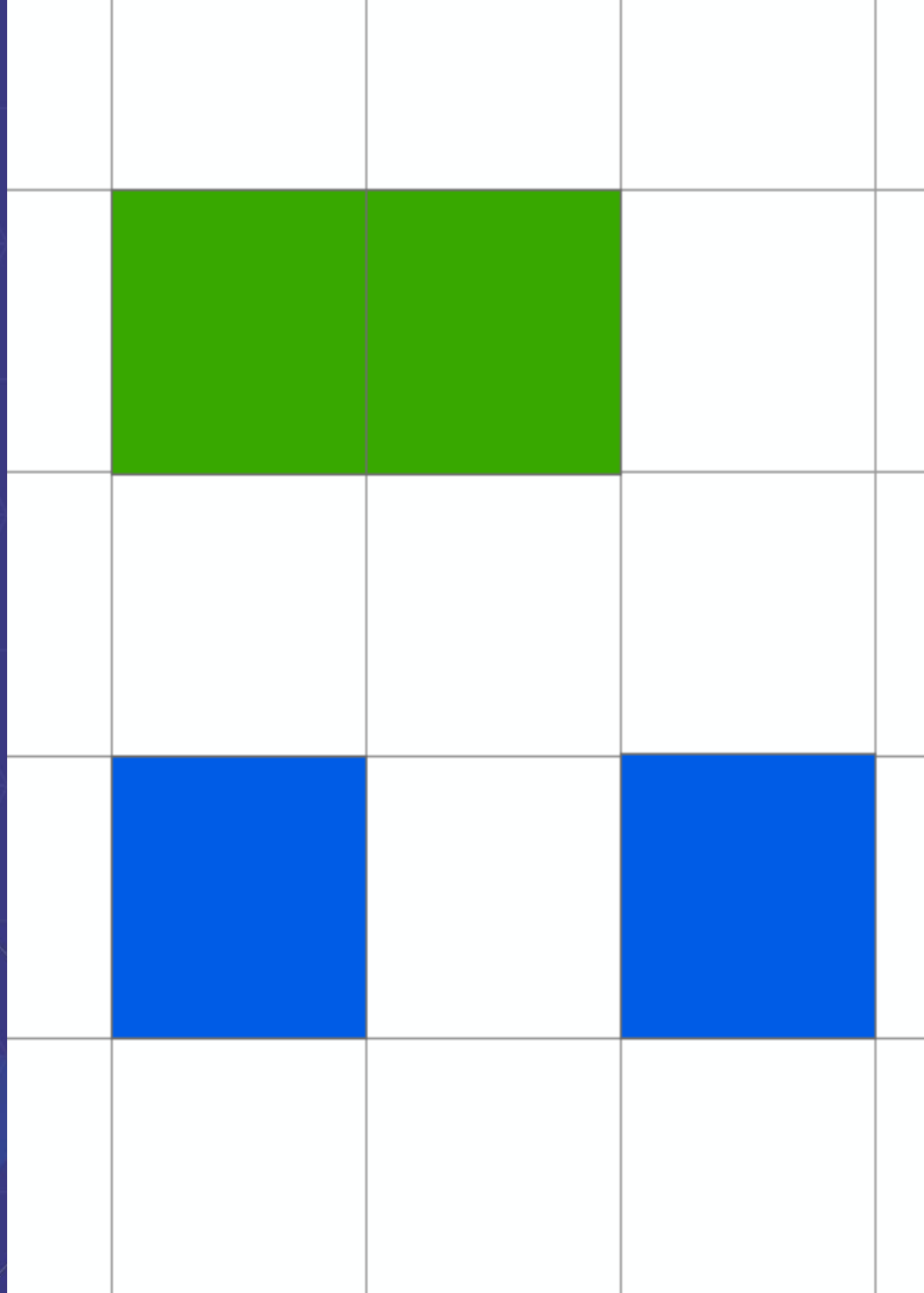
XY Tolerance

Editing Merge operation



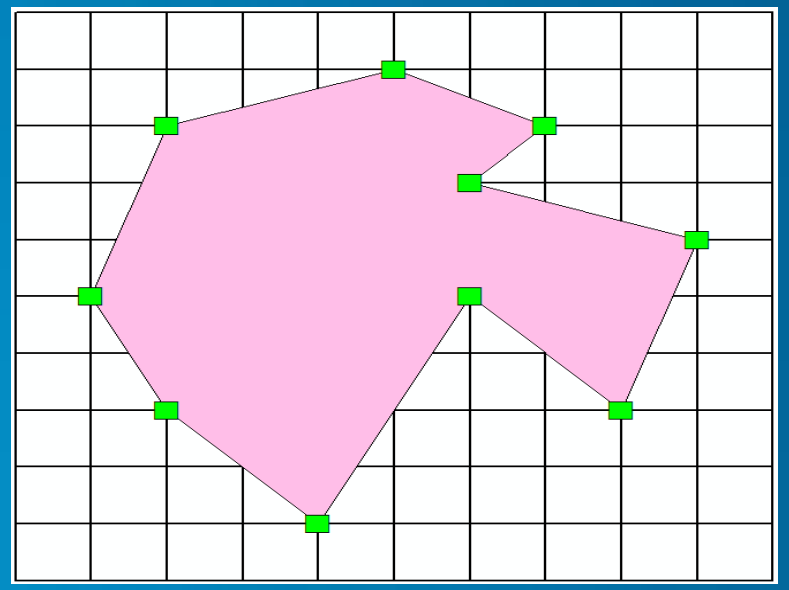
Merge Polygons

Demo



XY Resolution

- Numeric precision used to store x, y coordinate values
- All coordinates lie on coordinate grid
- Default value is 0.0001 meters or equivalent
  - x_1 = 5.1234, x_2 = 5.1235 stored as unique coordinate values
  - x_1 = 5.12344, x_2 = 5.12345 both stored as 5.1234
  - Each square in grid is 0.0001 x 0.0001



Tolerance vs. Resolution

Tolerance	Resolution
Default = 0.001 meter or equivalent	Default = 0.0001 meter or equivalent
Used when doing something with geometry	Used to store geometry in database
Determines if points are considered equal	Determines number of decimal places to store

Resolution should be no greater than 1/10 of the tolerance

Highly recommended to use default values!

What do spatial references have to do with geometries?

- Geometry is a collection of points
- Spatial reference determines
  - where the coordinates are placed
  - how the coordinates interact with each other

How does a spatial reference affect a geometry?

- We need to know where to put the geometry on the map
- Could change the geometry visually or structurally
- An operation on features may give different results

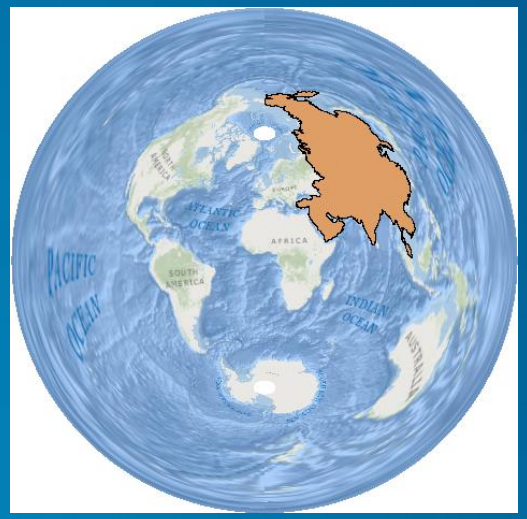
Where is my data?

Demo

Spatial reference can change the geometry

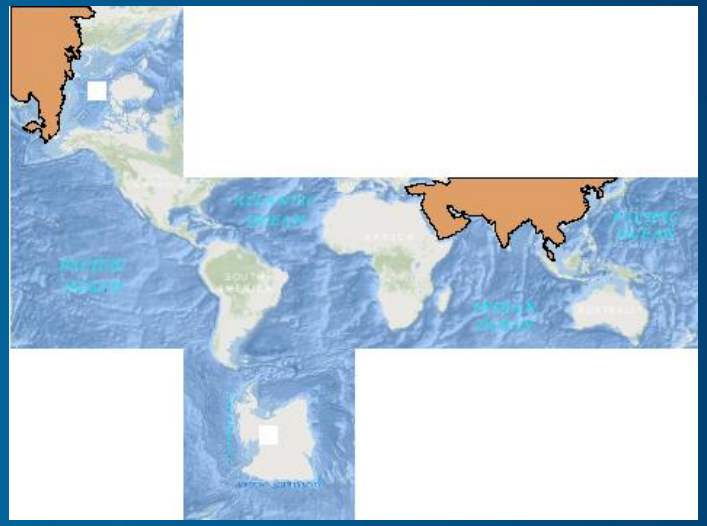
Here we have the same geometry in 4 different spatial references

WGS 84



Azimuthal Equidistant

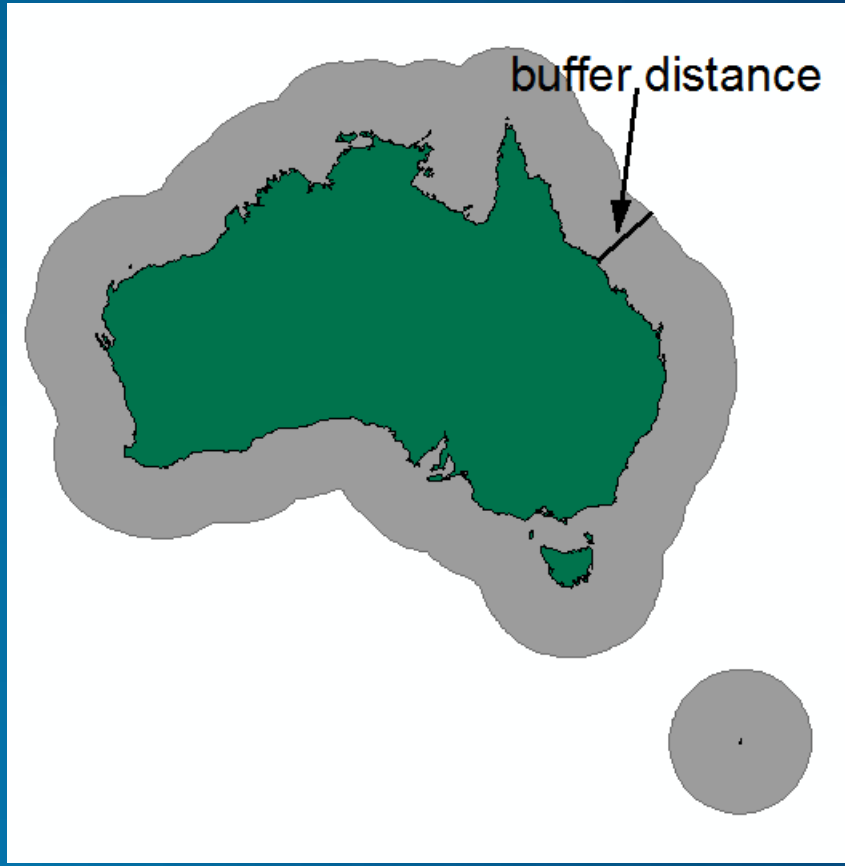
South Pole Gnomonic



Cube

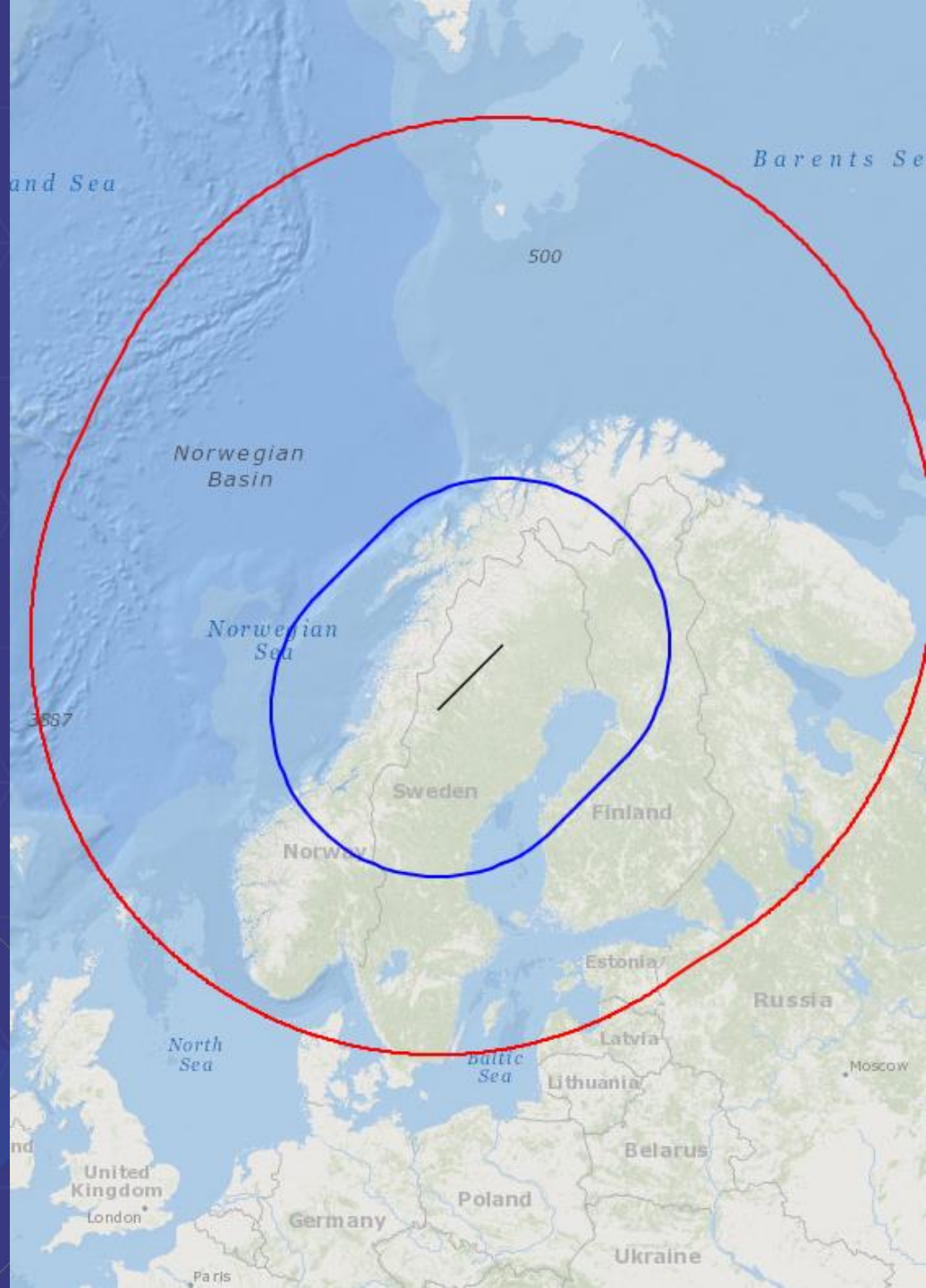
An operation on features may give different results depending on the spatial reference

For example, Buffer operation



Buffer and Spatial Reference

Demo



That’s all folks!

Don’t forget to fill out the survey

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Resources

http://resources.arcgis.com/en/help

Desktop → Guide Books → Map projections

Developer Help

List of ArcGIS APIs

Lining Up Data in ArcGIS, *Margaret Maher*

ESRI Technical paper: *Understanding Coordinate Management in the Geodatabase*

ESRI Technical paper: *Understanding Geometric Processing in ArcGIS*

Demos

All the demos are on GitHub at https://github.com/alocke/DevSummit2015

- ArcMap Demos
  - DevSummit2015.gdb
    - How do I find transformations? (Project.mxd)
    - Merge polygons (MergePolygons.mxd)
  - QM.gdb
    - Where is my data? (QM.mxd)
- JavaScript Demos
  - Why do we care if geometries are simple? (SimplifyPolygon.html)
  - Buffer and Spatial Reference (GeodesicBufferWebMercator.html and GeodesicBufferOther.html)